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National Aeronautics and Space Administration
Goddard Space Flight Center
Contract No. NAS-5-9299

ST - AM - 10481

THE ULTRAVIOLET SPECTRUM OF THE EARTH ACCORDING TO MEASUREMENTS FROM THE AES "COSMOS - 65"

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26 APRIL 1966

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Geomagnetizm i Aeronomiya
Tom 6, No. 2, 185 - 9,
Izdatel stvo "NAUKA", 1966

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SUMMARY

Measurements of atmosphere-reflected radiation were conducted on Cosmos-65 in the region 2250 - 3070 Å with a resolution of 15 Å. Two spectra are brought out in the work: the typical spectrum and the spectrum with maximum readings. Both were observed near the equator with the Sun near zenith.

When comparing the observed spectra with the computed, there is observed, first of all, a significant number of details of which the computed spectra are devoid. The reason for this is because the computed curves were plotted by a solar spectrum averaged in the 100 Å interval and thus considerably smoothed out. Fundamentally, however, the course of observed spectra and of the computed, just as their absolute intensities, coincide. Some distinctions exist on the edges of the spectra: no rise could be detected at $\lambda < 2400$ Å, whereas the drop at $\lambda \sim 2950$ Å was found to be less steep than might have been expected from the computed curves.

Comparison is made of the measured spectra with the results of photometric observations on rockets and satellites.

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An ultraviolet spectrophotometer was installed on the AES Cosmos-65 for measurement of solar radiation reflected by the atmosphere. The optical axis of the device was oriented at an angle of 7° to the direction at nadir. The orbit of the satellite had an inclination of 65° to equatorial plane.

A detailed description of the apparatus may be found in the work [1]; here we shall only recall some of its characteristics with reference to the ultraviolet spectrophotometer. It constitutes a dual diffraction monochromator operating in the region 2250 — 3070 Å. The resolution of the device is 15 Å and the effective visual angle is $2.5 \cdot 10^{-3}$ ster.; reading time: 1 min.

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* UL'TRAFIOLETOVYY SPEKTR ZEMLI PO IZMERENIYAM SO SPUTNIKA "KOSMOS-65".

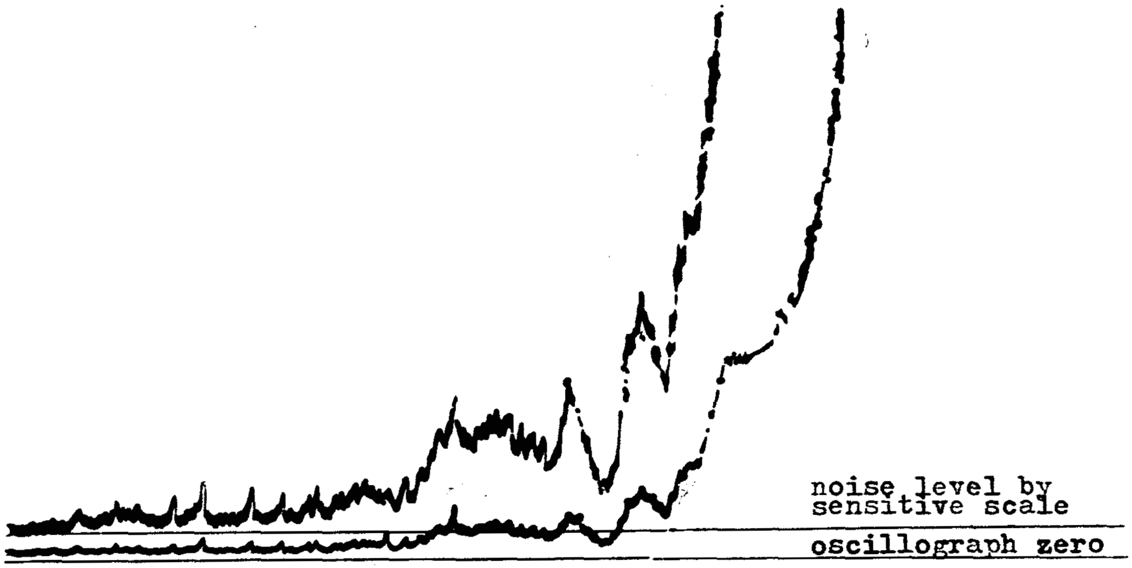
The apparatus was switched on at the daytime side of the Earth. Nearly 2500 spectra were obtained in the course of the flight. Their registration was conducted with the aid of a galvanometer oscillograph on a movie film. The ultraviolet spectrum was registered by two loops of different sensitivity; the latter's ratio was about 1 to 3. The energy distribution in the ultraviolet spectra varies not only with the zenithal distance of the Sun but also on the geographic latitude and from place to place, which is linked with local ozone concentrations. In its longwave part the shape of the spectrum is also influenced by the cloudiness, for at $\lambda > 2950$ Å a notable part of solar light reaches the lower layers of the atmosphere, which leads to albedo increase.

In spite of the variety of the enumerated factors, most of the spectra obtained in similar conditions, have a like structure. Below we shall compare and discuss two spectra obtained in the equatorial region in clear weather: 1) typical spectrum, 2) spectrum with maximum observed intensities. The first constitutes the bulk of spectra obtained in the tropical zone, the second ones are encountered rather seldom (by about a factor of 20).

We could judge on the character of nebulosity in the region of ultraviolet spectrum measurement not only from meteorological data but also the readings of the photometer operating in the region $0.6 - 0.85\,\mu$, the latter being a part of our airborne apparatus. The registrograms of both spectra are plotted in Figs. 1 a and δ, whereas Fig. 2 shows the same curves transposed into absolute units. To that effect we had to introduce the corrections for the dependence of apparatus' sensitivity on wavelength and on scale's nonlinearity.

The calibration of the device was performed in the same fashion as in the case of AES Cosmos-5 [1], that is, with the help of two standard lamps with uviol windows, a standard incandescence tube and a hydrogen lamp. Thus a sufficiently high precision was attained when determining the relative spectral sensitivity of the apparatus. The determination of the absolute sensitivity was rendered more co mplex by the fact that the utilized standard sources of light did not fill the entire aperture of the spectrophotometer. This led to a certain reconversion, which diminished the precision of the reduction to about 25 percent.

The theoretical computation of the spectrum of ultraviolet radiation, reflected by the Earth's atmosphere, was conducted by a series of authors.



Фиг. 1а

Fig. 1 a.

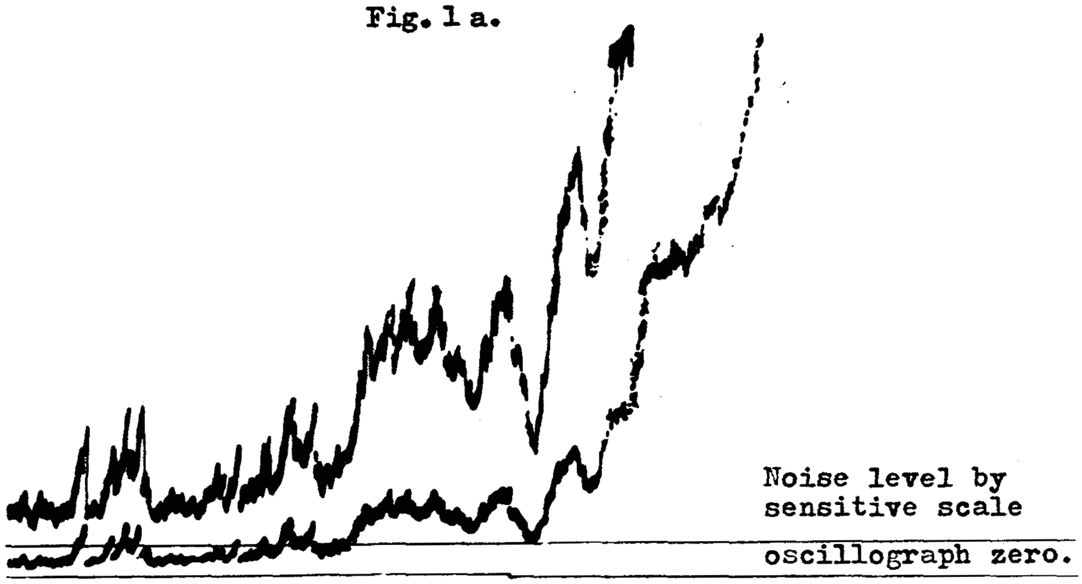


Fig. 1б

We plotted in Fig. 3 respectively the Chapman curve 2 [2], the Green curve 3 [3] and the curve 4 from ref. [4]. All these spectra were computed for a zenithal distance of the Sun equal to zero for a vertically-upward outgoing radiation.

The observed spectra of Fig. 2 have a great number of structural details not available on the calculated curves. This is due to the fact that

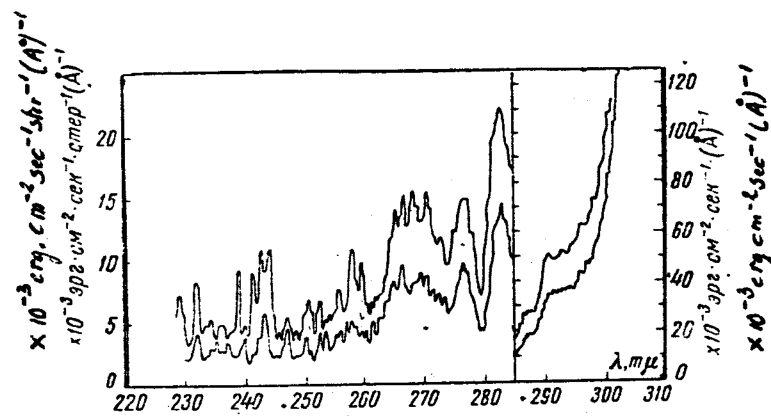


Fig. 2

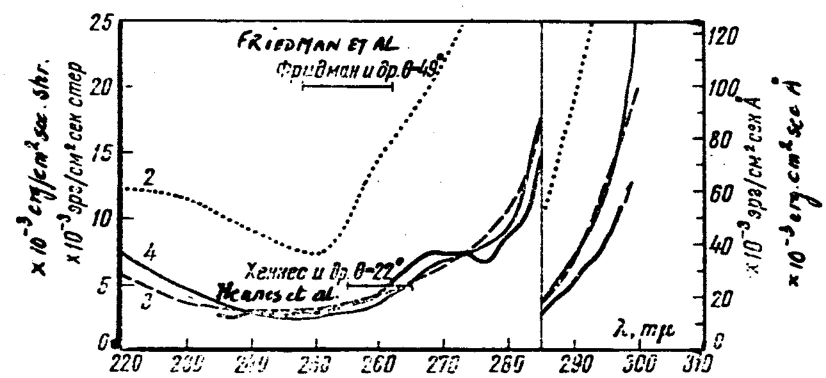


Fig. 3

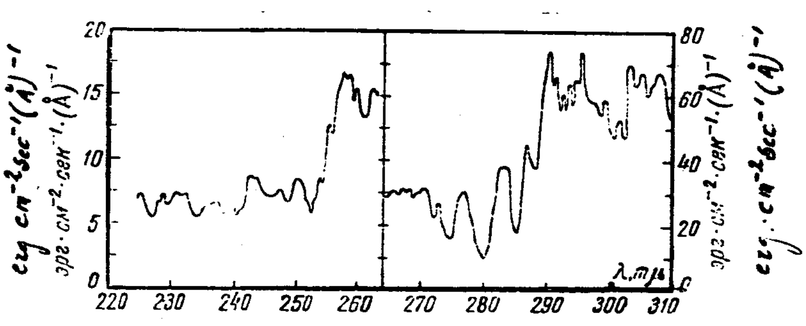


Fig. 4.

when obtaining the computed curves we utilized a solar spectrum averaged over wide intervals in 100 A; moreover, the computed curves were plotted by points separated by intervals of about the same magnitude. For comparison we brought out in Fig. 3 a typical observed spectrum, averaged for 100 Å intervals (curve 1). The spectra 3 and 4 are fairly close to the spectrum obtained by us, the spectrum 2 exceeds it by about 3 times and exceeds even the maximum spectrum of Fig. 2. In spite of the analogy between the observed spectrum, averaged in 100 Å intervals, and the computed spectra [3, 4], some discrepancies should be noted. In our spectra, we failed to detect any tendency to rise at $\lambda < 240\mu$. Later, the spectrum drop at $\lambda \sim 295\mu$ was found to be less steep, which may have been expected from the computed curves.

The ultraviolet spectrum reflected by the atmosphere is determined mainly by vertical distribution of ozone, and this is why the discrepancies between the results of measurements and various computations will always take place on account of the difference in the vertical distribution of ozone, assumed in the calculations and factually observed at points of measurement.

In order to determine the spectral albedo of the terrestrial atmosphere, it is necessary to compare the observed spectra with the solar spectrum. Spectra of the Sun, borrowed from the works [5 —— 7] and averaged over 15 Å intervals, are plotted in Fig. 4. The absolute standardization of these spectra was performed on the basis of solar spectrum measurements in the near-ultraviolet by Dunkelman and Scolnik [8]. Similar measurements were recently carried out by G. F. Sitnik [9], who obtained for the solar constant a value of 2.00 cal/cm^2 min., close to the Johnson result, but on the basis of different values of ultraviolet and infrared corrections. The Sitnik measurements in the ultraviolet region give values of absolute intensity of solar radiation 30 percent lower than those of [8]. These values are closer to the earlier measurements by Pettit [10]. During the analysis of atmosphere spectra, the absolute values of solar radiation intensity, borrowed from [5 — 7] and plotted in Fig. 4, were multiplied by 0.7.

Comparison of the solar spectrum with those of the atmosphere, obtained with about identical resolution, allows to detect a great analogy in the structure of both spectra. Their details are identical; however, the drop in atmosphere spectra with wavelength decrease is much steeper than in the solar spectrum, which is induced by rise of absorption by ozone.

When comparing the spectra it is possible to ascertain that various details of the solar spectra recur in the atmosphere spectra with a different degree of clarity. Moreover, in different atmosphere spectra even identical details are not always proportional. This is partly explained by the fact that the device's outlet slit shifts by steps of 10 Å and not continuously, while performing the spectrum reading, and has within the 7 Å limits a certain clearance. Another cause consists in the characteristic variation of the ozone layer.

When varying near the ozone band maximum the light fluxes were near threshold. This is why the measurements in this region are beset with notable errors. At measurements of small signals the errors increase on account of noiseinstability effect, device's nonlinearity at small signals and also because the signal and the noise are compunded as squares. Although the last two factors were taken into account during analysis of spectra, it did not fully prevent the errors from increasing.

The atmosphere albedo monotonically decreases in the region investigated as the wavelength diminishes; this is due to absorption by ozone. Compiled below are the mean albedo values for 100 Å intervals. In order to obtain the albedo we must know the atmosphere's scattering indicatrix, which is dependent on the vertical distribution of ozone and whose calculation is rather cumbersome. This is why we assume for simplicity the atmosphere to be here diffusively-reflecting

λ, Å	2600	2800	2850	2900	2950
α, %	0.1	0.115	0.135	0.16	0.215

The spectra obtained by us may be compared with the earlier conducted photometric measurements aboard rockets and satellites. The results obtained by Hennes et al [11] and Friedman et al [12] are brought out in Fig. 3. A light filter with transmission maximum at 2600 Å and at curve width half way from transmission maximum of 100 Å was utilized in [11]. In [12] the light filter's transmission maximum was at 2550 Å, and the curve width halfway from transmission maximum of 140 Å. The zenithal distance from the Sun during these measurements was respectively of 22 and 49°. The result of [11] was equal to $5 \cdot 10^{-3}$ erg/cm^2 sec ster Å, that of [12] — $2 \cdot 10^{-2}$ erg$\cdot$cm$^2\cdot$sec$\cdot$sterad$\cdot$Å. These values may be approximately reconverted for the case when the Sun is at zenith.

Applying the method of [3] and assuming that the percent of ozone content in the air does not vary with height above 40 km (parameter $\nu = 1$), we obtain

$$I^0 = I_0 \frac{1 + \cos^2\theta}{1 + \sec\theta}.$$

In this case the measurements of [11] must have given $5 \cdot 10^{-3}$ erg$\cdot$cm$^2\cdot$sec$\cdot$ster$\cdot$Å, and those of [12] — $3.5 \cdot 10^{-2}$erg/cm$^2\cdot$sec$\cdot$ster$\cdot$Å.

At $\nu = 0.66$, which satisfies best the results of [12], the last quantity would have been equal to $3.25 \cdot 10^{-2}$. The measurements of [11] agree rather well with our own; a significant part of spectra obtained by us for small zenithal distances from the Sun, had readings $\sim 5 \cdot 10^{-3}$ erg/cm$^2\cdot$sec sterad$\cdot$Å in the region 2600 Å. Measurements of [12] exceed substantially the intensity maxima obtained by us in the region 2550 Å.

The authors extend their thanks to Yu. V. Yaromenko, V. P. Malin and M. B. Glot, who have been very helpful in the preparation of the current experiment.

**** THE END ****

Moscow State University
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Received on
24 November 1965.

Contract No.NAS-5-9299
Consultants & Desègners, Inc.
Arlington, Virginia

Translated by ANDRE L. BRICHANT
on 25 - 26 April 1966.

REFERENCES

[1].- A. I. LEBEDINSKIY, V. A. KRASNOPOL'SKIY, A. P. KUZNETSOFF, V. A. IOZENAS.- Sb."Issl.Kosm.Prostr." Izd-vo NAUKA, 77, 1965.

[2].- R. N. CHAPMAN et AL.- Grophys.Corp.Amer.Rept, 35A, 61, 62, 1962.

[3].- A. E. S. GREEN.- Appl.Opt., 3, No. 2, 203, 1964.

[4]. V. A. KRASNOPOL'SKIY.- Geom. i Aeron. 6, No. 2, 298, 1966.

[5].- N. L. WILSON, R. TOUSEY, J. D. PURCELL, F. S. JOHNSON.- Astroph. J. 119, 1954

[6].- H. H. MALITSON, J. D. PURCELL, R. TOUSEY, C. F. MOORE, Ib. 132, 746, 1960.

[7].- M. P. THEKAEKARA.- NASA SP-74., Washington D. C., 1965.

[8].- L. DUNKELMAN, R. SCOLNIK.- J. Opt.Soc.America, 49, No. 4, 356, 1959.

[9].- G. F. SITNIK.- Astronom. Zh., 1, 59, 1965.

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continuation

[10].- E. PETTIT.- Astrophys. J. 91, 159, 1940.

[11].- J. P. HENNES, W. B. FOWLER, L. DUNKELMAN.- J.Geophys. Res., 69, 13, 2835

[12].- R. M. FRIEDMAN, R. D. RAWCLIFFE, G. E. MELOY.- J. Geophys. Res., 68, No. 24 6419, 1963.

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